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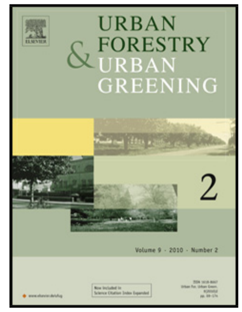

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Appraisal of social-ecological innovation as an adaptive response by stakeholders to local conditions: mapping stakeholder involvement in horticulture orientated green space management

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Dennis, Armitage and James: Innovation in social-ecological systems

Urban Forestry and Urban Greening

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Highlights:

- Social-ecological innovation in urban areas demonstrates an adaptive response to both social and ecological levels of deprivation.
- Poor but improving social conditions were important in the emergence of innovation.
- Levels of domestic green space in particular were closely associated with frequency of social-ecological innovation.

Abstract

Urban areas are hubs of creativity and innovation providing fertile ground for novel responses to modern environmental challenges. Previous studies have attempted to conceptualise the ecological, social and political potential of social-ecological innovation in urban green space management. However, little work has been conducted on the social-ecological conditions influencing their occurrence and distribution. Further research is therefore necessary to demonstrate whether stakeholder stewardship of green resources contributes towards adaptive capacity in social-ecological systems. The research reported here explored the extent of organised social-ecological innovations in a continuous urban landscape comprising three adjoining metropolitan areas: Manchester, Salford and Trafford (UK). Examples of horticulture orientated organised social-ecological innovation were identified using a snowball-sampling method. Their distribution, explored with GIS and remote sensing technology, was found to be significantly associated with levels of both, social and ecological, deprivation. The study presented social-ecological innovation as an adaptive response to environmental stressors, conditioned by specific social and ecological parameters in the landscape. It therefore provides empirical support for social-ecological innovation as a valid ingredient contributing to resilience in adaptive social-ecological systems. Not only do such collective community-led elements of natural resource management warrant acknowledgement in urban green space planning, but their distribution and productivity may provide a valuable social-ecological laboratory for the study of polycentric governance and adaptive capacity in the urban environment.

Introduction

Urbanisation has been presented as an environmental process which presents some of the greatest challenges to, but also offers some of the greatest opportunities for, the adaptive management of ecosystem services through innovative and adaptive natural resource governance (CBD, 2012). According to resilience thinking (Gunderson, 2000; Berkes et al., 2003; Walker et al., 2006), diverse social-ecological and innovator networks may hold some of the keys to future adaptive urban management (Armitage, 2005; Janssen et al., 2006; Cantner et al., 2010). Walker et al. (2004) suggested that the successful management of future changes within social-ecological systems is dependent on three important attributes: resilience, adaptability and transformability. They described resilience as the ability of a system to undergo disturbance while maintaining its essential functions; adaptability as the ability of core actors within the system to influence resilience; and transformability as the capacity to assemble an essentially new system when the current one becomes untenable. The cycles of transformation and adaptation which underpin such close-knit social-ecological systems are described by the related concept of the adaptive cycle (Gunderson and

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Holling, 2002). A key element in the ability of systems to withstand, adapt to, or recover from internal and external environmental stresses is the capacity to adapt (Gunderson and Holling, 2002). Adaptation to change can take place at various stages in the adaptive cycle and at various scales within interrelated cycles operating at differential spatial and temporal scales (Holling et al., 2002a; Krasny and Tidball, 2015).

One means though which adaptive capacity may be increased in social-ecological systems is through polycentric approaches to resource management (Folke et al., 2005; Lebel et al., 2006) which can diversify available responses to environmental challenges (Elmqvist et al., 2003). The CBD (2012) report called for the appropriate decentralisation of natural resource management, a view shared by the authors of the Millennium Ecosystem Assessment (2005) as well as researchers who have studied the resilience of social-ecological systems (Ernstson et al., 2008; Shava et al., 2010; Krasny and Tidball, 2012; Colding and Barthel, 2013; Barthel et al., 2014).

Although the polycentric governance of green resources which promotes stakeholder engagement and local stewardship of ecosystem services has been promoted as an essential ingredient of adaptive capacity (Andersson et al., 2007; Ernstson et al., 2010; Biggs et al., 2012), much of the exploration into adaptive responses by communities to environmental stresses has focussed on those which have occurred in the wake of natural disasters (Gunderson, 2010; Tidball et al. 2010; 2012; Krasny and Tidball, 2015). Such work has primarily focussed on individual case studies of adaptive responses to disturbing events and environmental tipping points (Tidball et al., 2010; Krasny and Tidball, 2012; 2015). These catastrophic events cause associated social-ecological systems to enter the *collapse* or (*release*) stage of the adaptive cycle (Holling et al., 2002b) and, as such, provide opportunities to evaluate, with hindsight, the resilience and vulnerability of such systems. They also permit an assessment of the range of innovative responses which emerge during the “back-loop” phase characterised by re-organisation and renewal (Carpenter and Brock, 2008). Post-disaster scenarios, due to their severity, naturally provoke widespread concern, scrutiny and opportunity for a diverse range of responses at local, regional and national levels of agency. Accordingly, such large-magnitude disturbances have provided valuable case studies towards an appreciation of social-ecological innovation and adaptation to change. It is true that radical community-led responses to urgent social-ecological challenges are vital to recovery and regeneration in post-disaster “red zones” (Okvat and Zautra, 2014; Tidball and Krasny, 2014). However, the building of social-ecological resilience, through a shift towards more polycentric forms of governance (Ernstson et al., 2010; Biggs et al., 2012), relies heavily on traits which emerge gradually and locally such as trust, sense of place and social capital (Ernstson et al., 2008; Krasny and Tidball, 2015). Nowhere are such qualities more relevant than in cities where they support responses to both the social and ecological challenges of urbanisation (Ersntson et al., 2010; Krasny and Tidball, 2015).

Social-ecological innovation in urban areas

The cumulative effect of relatively small environmental disturbances over time can be just as destructive as high-magnitude low-frequency events through the crossing of environmental thresholds and the formation of “broken places” (Krasny and Tidball, 2015). Such, often urban, areas are typified by social disinvestment and ecological degradation, conditions which can stimulate equally adaptive responses from local stakeholders (Okvat and Zautra, 2011). Given the “slow-burn” nature of such incremental social-ecological deprivation (Tidball et al., 2014), the responses exhibited by communities are likewise often localised, gradual and inconspicuous. However, it has been demonstrated that, for example, local small-scale civic-ecological responses to both social and environmental disinvestment can reap rewards not just locally (Krasny et al., 2014) but also through wider impacts on policy and decision-making at higher levels of governance (Folke et al., 2005; Ernstson, 2008).

Not only do cities appropriate vast ecological resources at local and global scales, but the distribution of those resources within the urban region, tend to echo familiar patterns of socio-economic

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inequality among the population demography (Haughton, 1999; Schweitzer and Stephenson, 2007). Urban areas exhibit high levels of environmental inequality in terms of green space provision and, therefore, natural resources take on disproportionate cultural significance (UK NEA, 2011). Such a situation heightens the social-ecological tensions which may provide a rich context for examples of environmental engagement (Cattell, 2001).

Local social-ecological innovation, emerging from the broader civic ecology movement, has received increasing attention as an effective and desirable contribution to a decentralised approach to natural resource management, specifically in urban areas (Barthel et al., 2011; Colding and Barthel, 2013). Much attention has been paid in the literature to the potential gains stemming from the broad spectrum of practices classed as civic ecology in urban areas (Krasny and Tidball, 2012; Krasny et al., 2014; Krasny and Tidball, 2015), and to the benefits and organisational structures associated with community gardens (Wakefield, et al., 2007; Pudup, 2008; Kingsley et al., 2009; Barthel et al., 2010; Okvat and Zautra, 2011). Furthermore, studies have demonstrated that social-ecological action is associated with increasing productivity of urban green space with user participation bearing a positive influence both in terms of levels of biodiversity (Dennis and James, 2016a) and ecosystem service provision (Dennis and James, 2016b). Innovative land-use and collective green space management in urban areas include, but are not limited to, community gardens, collectively managed allotments and farms, permaculture projects, forest gardens, pocket parks, and sites of environmental education and training. The majority of the research on such activity, however, has been of a qualitative nature and has adopted a largely conceptual stance in its appreciation of the emergence and impact of such approaches. For example, ethnographic studies investigating the views and goals of participants in social-ecological actor groups have succeeded in elucidating the motives which drive such engagement (Glover, 2004; Glover et al., 2005; Jones, 2005; Kingsley et al., 2009; Corrigan, 2011; Rosol, 2012; Green and Phillips, 2013). These studies have unpicked the genesis and organisational structure of collaborative groups involved in environmental stewardship and the importance of social-ecological networks at various levels of agency has been highlighted and promoted (Andersson, 2007; Ernstson et al., 2008; Biggs et al., 2010).

The presence and distribution of social-ecological innovation in the urban landscape, however, have hitherto been poorly understood (Janssen et al., 2006). Unless the extent of such practices in the urban landscape is contextualised, community-led stewardship of green space cannot be said to comprise a substantial or adaptive element in urban social-ecological systems. In order for social-ecological innovation to be confirmed as a valid contribution to adaptive capacity in the management of urban landscapes, it is necessary to demonstrate that such engagement occurs relative to local environmental conditions, as an adaptive response to local challenges. Furthermore, this needs to be done at the landscape scale so as to assess the occurrence of collaborative groups as a coherent body of innovation extant throughout the social-ecological system. Such an approach would confirm the contribution to adaptive capacity within systems by civic ecological intervention, something which has hitherto only been described through individually selected case studies (e.g. Holland, 2004; Kingsley et al., 2009; Patterson et al., 2010; Green and Philips, 2013; Krasny and Tidball, 2015). Such studies, although insightful, fail to describe innovative stakeholder-led action as a coherent phenomenon exercising influence throughout landscapes and their associated social-ecological systems. A detailed, quantitative evaluation of the presence and distribution of social-ecological innovation in urban landscapes is, therefore, timely. Without this, it remains difficult to evaluate stakeholder-led natural resource management as being truly adaptive in nature. Addressing this gap in knowledge is important as, according to established criteria for effective social-ecological innovation (Olsson and Galaz, 2012), novel approaches to local environmental management should reflect a consideration of, and adaptability to, both social and ecological challenges.

Study overview

A clearer understanding of the environmental conditions associated with local social-ecological action, would not only inform an appraisal of the contribution of such innovation towards adaptive

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capacity, and local environmental governance but also identify those circumstances, or "traps", which may hinder its occurrence (Carpenter and Brock, 2008). In order to address this current gap in knowledge, the authors of this paper undertook an exploration and evaluation of instances of organised social-ecological innovation (OSEI) as adaptive responses to local environmental conditions in an urban landscape. Specifically, the local contexts of sites of social-ecological innovation were explored for evidence of levels of both physical and social deprivation. The rationale was that, if such innovation can be said to comprise a coherent adaptive response to environmental pressures in the landscape, it should occur in those areas most in need of its potential social and ecological benefits (Holland, 2004; Olsson and Galaz, 2012; Dubé et al., 2015; Krasny and Tidball, 2015), namely those subject to greater than average levels of social and ecological disinvestment. This hypothesis was tested by mapping examples of OSEI within a north-west England conurbation and exploring whether their distribution was influenced by separate measures of ecological and social deprivation.
The study area for the research was comprised of three adjoining metropolitan districts in Greater Manchester (Manchester, Salford and Trafford). These districts together form a coherent inner-city zone of continuous suburban areas (Manchester City Council, 2012). As such these three districts form, collectively, the most densely populated part of the conurbation and provided a suitable context for research towards an understanding of the emergence of community-led urban green space management.

The term *organised* social-ecological innovation is used to differentiate the subject of this study from other highly informal or illegal forms of social-ecological activity such as seen in examples of guerrilla gardening (see Hardman and Larkham, 2014). OSEI, as defined here, differs from a guerrilla approach as it generally aims at the integration and cooperation of community members and land-owners towards the establishment of land-use rights for local residents. However, the study was aimed at an appraisal of social-ecological innovation as an adaptive response by stakeholders to local conditions in the study area landscape. For this reason, projects originating from formally proposed initiatives, for example those led by large regional umbrella organisations such as the Forestry Commission, Natural England, Red Rose Forest, Mersey Valley Wardens or local authority-managed projects, were excluded from the data collection. This allowed for a greater focus on community-led innovative uses of local pockets of open space.

Methods

Identification of Sites

In order to facilitate the social-ecological analysis of site locations, it was necessary to map examples of OSEI as geographically discrete phenomena, entered into a GIS as XY point data. Therefore, multi-locational urban greening projects or initiatives with a broad geographical range such as tree, wildflower and container planting schemes would have confounded a standard approach to the spatial analyses. For these reasons OSEIs, to be included in the data collection process, were defined as community resources consisting of single sites under stakeholder-led management occupying at least $100m^2$ of uninterrupted open space.

Between July 2012 and July 2014, information on existing examples of organised social-ecological innovation in the study area were gathered using a snowball sampling approach (Goodman, 1961) which began with the use of internet search engines and subsequent consultations with social-ecological actor groups in the study area until no additional projects were discovered. Information was initially gathered on prospective examples of OSEI from the Google search engine using combinations of the search terms "civic ecology", "community greening", "garden", "allotment", "orchard", "sustainable", "projects" and location-words "Manchester", "Trafford" and "Salford". Websites for known local sustainability and environmental action groups were visited periodically during the course of the data collection phase and existing reports on the status of community gardening and urban agriculture by local authorities were likewise consulted (Kazmierczak et al., 2013). Other prominent groups involved in social-ecological activities in the area (Kindling Trust, Start

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Salford, Federation for Urban Farms and Community Gardens, Action for Sustainable Living) were consulted directly.

Spatial Distribution of Sites

The locations of each site were initially mapped using Google Earth 9. Use of satellite imagery provided by the latter ensured that the geographical positions of open spaces under stakeholder management were successfully located rather than premises or administrative addresses associated with actor groups. Once the snowballing sampling process had reached the point of data saturation the national grid coordinates of each site identified were obtained from a postcode look-up table (Ordnance Survey, 2012) and verified against the initial Google Earth locations. In the event that post codes were obsolete or offered an unsatisfactory level of spatial precision, grid references were confirmed using the online spatial tool www.gridreferencefinder.com. Sites were then mapped, within ArcGIS.9 against administrative boundary data for the lowest level UK administrative geographical units: lower super output areas (LSOA), downloaded from the UK government's Office for National Statistics (ONS, 2001). Lower super output areas are used by the UK government to disseminate small area statistics and have populations of between 1,000 and 3,000 persons, and between 400 and 1,200 households (ONS, 2016).

Area physical and social characteristics were mapped through use of the ArcGIS.9 *join and relate* tool. The ArcGIS.9 *intersect* and *spatial join* tools were used to determine the social-ecological character of site locations, and *select by location* was used to differentiate LSOAs with and without instances of OSEI. All spatial analysis tools were accessed through the ArcGIS.9 toolbox. Subsequent analyses compared the physical and socio-economic characteristics of site localities with those of the rest of the study area. This was achieved by separating lower super output areas (LSOAs) in the study area into two groups: those where OSEIs were recorded (Group 1) and those where it was not (Group 0). The resulting attribute tables were then entered into IBM SPSS.20 statistical software.

Analysis of Physical (land-cover) Characteristics

The physical environments in which OSEIs were recorded were explored using the Ordnance Survey-derived Generalised Land Use Database (GLUD: ONS, 2005). These data, consisting of a range of principle land-cover categories, are available for all lower super output areas in England and are provided in units of $1000m^2$ per LSOA. Land cover by green space and domestic gardens (as a percentage of total land cover) was then compared (Mann-Whitney U-test) between the two area groups 1 and 0. This was done in order to determine the unique local conditions in the physical environment associated with the emergence of OSEI in the study area landscape. Values for percentage cover were calculated from the relevant GLUD dataset land-cover categories. In addition to the GLUD data, remotely sensed Landsat data (bands 3 and 4) were downloaded (NASA, July 2013) and, using ERDAS Imagine.10 software, the Normalised Difference Vegetation Index (NDVI) for the study area was calculated. The NDVI is calculated from the reflectance ratio of red and near-infrared light by vegetation (Pettorelli et al., 2005). The NDVI values can range from -1 to +1, indicating the absence and presence of vegetation respectively.

Socio-economic Analysis

Site locations were also explored for socio-economic characteristics. Experian MOSAIC data (Experian Limited, 2007) on neighbourhood characteristics were used to categorise areas as defined by the most representative MOSAIC group per LSOA. The MOSAIC UK is a geodemographic dataset designed to generate consumer classifications of households for commercial and research purposes. The classification is built on variables derived from demographic, socio-economic and consumption, property and location data (Experian Limited, 2006). The MOSAIC UK classifies UK households into a typology of 11 groups. These are presented in Table 1.

As for the analysis of land-cover data, the study area was divided into two groups and analysis was performed using a Chi Square test to determine if the two were statistically discrete based on this appraisal of local socio-economic conditions.

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Index of Multiple Deprivation (IMD) data were obtained (DCLG, 2004; 2010) to allow analysis of socio-economic deprivation at site localities. The IMD is built from thirty-eight separate indicators derived from UK census data across seven distinct domains relating to discrete forms of social deprivation. The seven domains are: Income Deprivation, Employment Deprivation, Health Deprivation and Disability, Education Skills and Training Deprivation, Barriers to Housing and Services, Living Environment Deprivation, and Crime. For each indicator, a denominator (based on mid-year population estimates) seeks to measure the number of people (or households) that are 'at-risk' of being defined as deprived. Factor analysis is then applied to assign weights to each indicator resulting in a final (dimensionless) IMD score as a measure of overall social deprivation relative to other LSOAs in the dataset, where a higher score indicates a greater relative degree of area deprivation.

Locations of Sites (Group 1) were analysed through a comparison of means (Mann-Whitney U-test) with that of the remainder of the study area (Group 0). Accordingly, the spatial contexts of sites were established by examining the physical and socio-economic data available on the respective lower super output areas within which they occurred, relative to areas they did not. The relationship between the occurrence of OSEI and local area deprivation was also explored by calculating the frequency at which the phenomenon occurred at discrete levels of both physical and social deprivation. All statistical analyses were carried out using IBM SPSS.20.

Results

Identification of Sites
The two-year snowball exercise identified 102 sites in the study area. All sites were involved in some form of horticulture, principally focussed on the cultivation of fruit and vegetables.
Figure 1 presents the distribution of sites - plotted against the normalised difference vegetation index (NDVI) of the study area.

Analysis of Physical (land-cover) Characteristics
Based on the vegetative cover in Figure 1 many sites appeared to occur in areas with a relatively low vegetative index and high levels of urbanisation. Exceptions were sections immediately to the west of Manchester city centre and the southern-most tip of the study area, which although seemingly highly built-up areas, contained few sites. These areas contained extensive, non-residential infrastructural features; namely, Trafford Park (the first planned industrial estate in the world and the largest in Europe) to the west and Manchester Airport to the south.

Although mean values for total green land-cover were significantly different ($p = 0.017$) between groups 0 (mean = 58% ±15%) and 1 (mean = 52% ±17%), there was a significant distinction between public and private green space types. Mean land cover by domestic gardens differed significantly ($p < 0.001$) between group 0 (mean = 29% ±15%) and group 1 (mean = 22% ±14%). In terms of specifically public green space, however, groups were not significantly discrete ($p = 0.255$). Figure 2 presents a summary of site frequency occurring at each level of domestic garden cover in the study area.

Socio-economic Analysis
A comparison of mean Index of Multiple Deprivation scores for Group 1 LSOAs (mean = 39.03 ±17.06) and Group 0 (mean = 32.56 ±19.84) demonstrated a high degree of statistical significance ($p = 0.004$). Figure 3 contains a summary of the frequency of sites occurring at each level of Index of Multiple Deprivation score for the study area.

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Although the domestic garden cover and IMD score variables shared a significant level of correlation (Spearman's Rho = 0.329; $p < 0.001$), they exhibited differential patterns of association with the occurrence of OSEIs. The data in Figure 3 demonstrate that the occurrence of sites increased with growing severity of deprivation up to IMD scores of between 30 to 40 (study area mean = 33.51). Above this threshold, however, examples of OSEIs continued to occur but with lower frequency before reducing dramatically (<2% of the total) in areas with deprivation equal to 70 or over (study area max = 81.58).

Comparing 2010 IMD data to the previous 2004 publication demonstrated that Group 0 areas had improved within this time period (mean IMD change = -3.62 ±33.19) but that localities of OSEIs (Group 1) presented a much greater mean improvement (mean change = -15.73 ±28.01). The mean difference was significant at $p = 0.002$ and is illustrated in Figure 4 (with standard deviation error bars).

Chi-squared test on Experian MOSAIC data revealed that the two groups were statistically discrete in terms of the most representative MOSAIC household category ($p < 0.001$). These data are summarised by MOSAIC category (as percentage make-up of each group) in Figure 5.

Discussion

The resilience of social-ecological systems is largely a function of the ability to adapt to internal and external disturbances (Gunderson and Holling, 2002). In highly human-dominated landscapes such as urban areas, system resilience is greatly dependent on the ability of core actors to increase adaptive capacity (Walker et al., 2004). Accordingly, the importance of social-ecological actors at the local scale has been acknowledged through the promotion of more decentralised approaches to natural resource management (Folke et al., 2005; MEA; 2005; Lebel et al., 2006). Here polycentrism plays a key role in the building of adaptive capacity by encouraging the diversification of responses to environmental challenges (Elmqvist et al., 2003). It has been recommended that polycentric governance in social-ecological systems may be enhanced by collaborative approaches to natural resource management (Ernstson et al., 2010) which promote stakeholder engagement, social-ecological learning and local stewardship of ecosystem services (Biggs et al., 2012). Informal, civic involvement in the management of urban green spaces has been increasingly posited as one of the social-ecological elements in the urban landscape which may contribute to forms of adaptive governance (Barthel et al., 2010; 2013). Case studies evaluating the occurrence, distribution and social-ecological contexts of community-led green space management have, however, been few. A need to quantify the occurrence of social-ecological innovation as a significant and adaptive ingredient in social-ecological systems has, therefore, remained unfulfilled.

The mapping exercise presented here revealed that organised social-ecological innovation held an extensive presence in the study area landscape (Figure 1). In terms of land cover, groups 0 and 1 differed most markedly across the domestic garden cover variable ($p < 0.001$) with public green space having no statistically significant relationship with the occurrence of sites. Such innovation was therefore more likely a response to levels of specifically domestic as opposed to public green space. The trend presented in Figure 2 demonstrates that decreasing domestic garden cover was closely associated with increasing frequency of sites (r^2 linear = 0.95; $p < 0.001$) with 36% occurring in those areas categorised as ≤10% cover.

That low levels of public green space were not, statistically speaking, associated with the presence of OSEIs suggests that such spaces may not be as highly valued by urban residents as are private, domestic gardens. A lack of, and desire for, the latter leading to collaborative use of common land, suggests that there may be a greater demand for those forms of recreation and provision associated

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with domestic gardens, such as horticulture and agriculture than those derived more readily from larger, open public green spaces. Francis (1987) noted that collectively-managed gardens are often disregarded by land authorities but that they provide a desirable alternative to city parks. This desirability stems from the opportunities for recreation at urban community gardens which typically involve a higher degree of physical activity, through horticulture and general site management, than those occurring in city parks. Given that a high proportion of sites were involved in food production, perhaps partly as a response to food poverty, a desire for horticultural opportunities not typically associated with specifically public green space types, could well be a key driver of innovative land use by communities.

Sites were more prominent in areas that exhibited significantly higher levels of social deprivation (Group 1 IMD score: mean = 39) than the rest of the study area (Group 0 mean = 33; $p = 0.006$). The data in Figure 3 reveal that the frequency of sites was significantly tied to IMD score but the relationship between the two exhibited much greater non-linearity (r^2 quadratic = 0.94; $p = 0.001$) than did that between site occurrence and domestic garden cover (r^2 linear = 0.95; $p < 0.001$). Although initially rising with increasing levels of multiple deprivation, the occurrence of OSEIs reduced noticeably beyond an IMD score of 40 with very few (<2%) occurring above an IMD score of 70. It follows that, despite specific levels of social-ecological deprivation accompanying the occurrence of sites, increasingly high levels of particularly social deprivation, over a given threshold, appear to impede such innovation. This conclusion is supported by site localities being associated with greatly *decreasing* levels of social deprivation relative to the rest of the study area (Figure 4) suggesting that improving social conditions support the emergence of local innovation. The data here revealed that OSEIs had been occurring in areas that were improving, in social deprivation terms, at a rate over 300% greater than the rest of the study area. The analysis of Experian MOSAIC data also gives weight to the notion of social mobility as an integral aspect of social-ecological innovation in the landscape. These data revealed that the two sample groups differed most across MOSAIC categories three (Suburban Comfort), five (Urban Intelligence) and six (Welfare Borderline). Very few (1%) of LSOAs in Group 1, for example, were most represented by neighbourhoods in the Suburban Comfort category as opposed to almost 20% in Group 0. The MOSAIC typology (Experian Limited, 2007) describes such households as occurring in affluent areas which are typically populated by successful white-collar workers and their families (Table 1). On the other hand, Group 1 had a higher percentage representation for the categories Urban Intelligence and Welfare Borderline (28% and 20%) than did Group 0 (10% and 11%). According to the MOSAIC descriptors these households are inhabited by mainly young, educated students or career starters encumbered by debt and living in inner-city housing (in the case of "Urban Intelligence") and by low-income, often state-dependent families in run-down areas which may suffer from high-levels of anti-social behaviour (in the case of "Welfare Borderline"). As such the locations of sites consisted of highly deprived areas but which contained a large proportion of neighbourhoods that were home to young, educated people of varying social classes living in relatively cheap housing in inner city areas (Table 1). Such members of the population may represent an element of social-ecological awareness in the landscape and a degree of social mobility. This, combined with the data on IMD change (Figure 4) suggests that social-ecological responses were associated with urban areas which have been historically subject to high levels of deprivation but which have benefited from recently improving social conditions, highlighting the potential significance of the latter in its emergence.

Levels of socio-economic deprivation exhibited a weak but highly significant correlation with the domestic garden cover variable which had a confounding effect on the delineation of the relative influence of the two. The levels of association between frequency of sites and both the land cover (r^2 = 0.95: Figure 2) and IMD score (r^2 = 0.94: Figure 3) variables were also comparable. Such delineation was not, however, necessary in order to quantify and test the emergence of organised social-ecological innovations as adaptive responses, which was the aim of this study. In this respect, the body of sites which made up the case study demonstrated a coherent landscape scale response to

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local environmental conditions and, therefore, an element which could contribute to resilience in urban social-ecological systems.

Limitations of the study

It was not possible to guarantee that all examples of social-ecological innovation occurring within the study area were captured through the data collection process. Furthermore, certain community greening activities were deliberately excluded from the spatial analysis. OSEIs, as defined here, were limited to the site-specific management of pockets of urban green space. As a result, other civic ecological activities such as community forestry, and habitat conservation and restoration were not evaluated. That said, a complete account of every instance of social-ecological action was not possible and, moreover, the method employed provided a large enough sample with which to conduct adequate statistical analyses. The quantitative approach employed provided a means through which to assess the scale and environmental milieu of OSEI as a coherent body of practice within the social-ecological system associated with the study area. Such methods did not, however, permit insight into the genesis of specific actor groups involved with OSEIs. Further work into the mechanisms of how groups form and grow around innovative land-use would inform attempts to encourage and support social-ecological engagement in urban areas where it would provide the greatest benefit.

By evaluating OSEI as an adaptive phenomenon the study provided insight into how such innovation, exhibiting adaptability by core actors, may contribute to social-ecological resilience (Walker et al., 2004; 2006). However, the work did not address the influence of OSEI on the transformability of systems (i.e. their ability to re-organise after entering the collapse and release stages of the adaptive cycle). Insight into this particular aspect of adaptive capacity only becomes possible after systems have undergone such change. However, the monitoring of innovative social-ecological actors in urban landscapes, of which this study provides a methodological example, may help to evaluate their role in the recovery of systems as they move into the post-collapse phase.

Conclusions

Social-ecological innovation as a response to local urban environmental conditions

The contexts of examples of social-ecological innovation as described here, presented the phenomenon as being, from a landscape scale view, responsive to social-ecological conditions. The emergence of social-ecological practices in such contexts, which saw 36% of sites located in areas with lower than 10% garden cover was, in particular, closely responsive to such a lack of domestic green space (Figure 2).

The emergence of sites, as well as demonstrating adaptive capacity, was simultaneously subject to the potential traps associated with the adaptive cycle framework. Specifically, whilst initially increasing in number with heightening socio-economic deprivation, site occurrence dropped sharply beyond IMD scores of 40 and very few were found in LSOAs subject to IMD scores of 70 or more. According to the theory of adaptive cycles, such areas represent "poverty traps" (Carpenter and Brock, 2008) where high levels of system stress, unfavourable circumstance or lack of leadership may prevent individuals from mobilising towards the pooling of communal resources. The identification of areas falling into such "traps" in the urban landscape could facilitate the targeting of vulnerable elements in social-ecological systems by urban planners and decision makers. Given the potential social benefits documented as issuing from collectively managed green space (Hynes and Howe, 2004; Pudup, 2008; Okvat and Zautra, 2011; Krasny and Tidball, 2015) such severely deprived areas would benefit from support from external agencies towards the establishment of local communally managed green resources. To such an end, horticulture with an emphasis on urban agriculture appeared to be an effective vehicle for the establishment of social-ecological engagement, confirming similar assertions in previous research (Francis, 1987).

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The study provided quantitative insight into the spatial characteristics of social-ecological intervention in the urban landscape not previously elucidated from purely qualitative, ethnographic or conceptual studies of the phenomenon (e.g. Krasny and Tidball, 2009; Schusler et al., 2009; Tidball and Krasny, 2011; Tidball and Weinstein, 2011; Kudryavstev et al., 2012). Further research into specific types of innovation and their distribution may provide a greater understanding of their diversity, adaptability and vulnerability in response to specific social-ecological configurations in the urban landscape. Detailed analysis of site management, design and the associated production of ecosystem services would also help to validate its contribution to the social-ecological resilience of urban areas.

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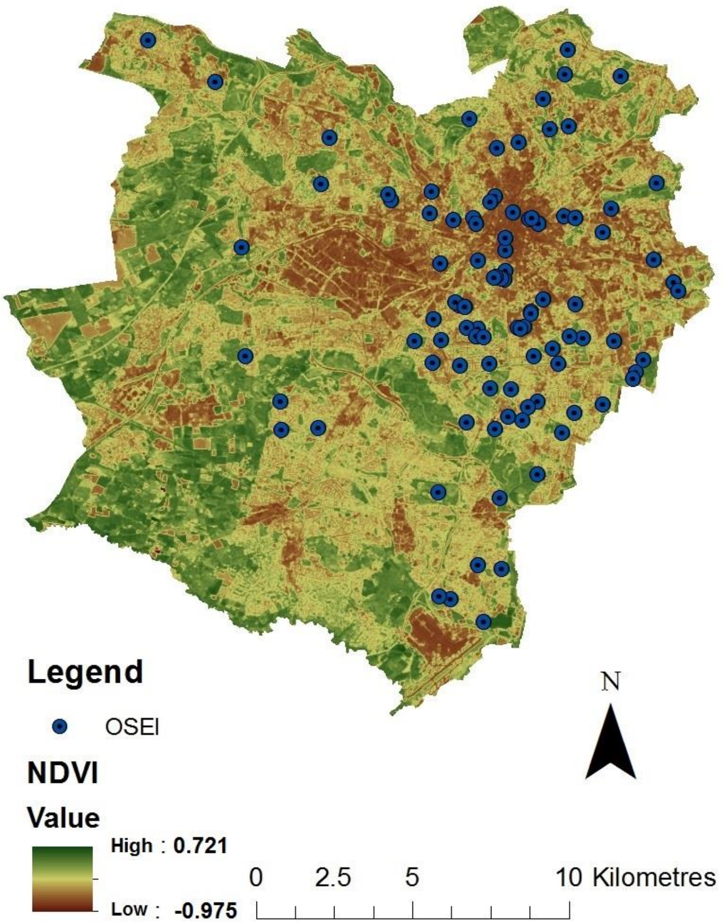

Figure 1: OSEI distribution and normalised difference vegetation index (ONS, 2001; NASA, 2013).

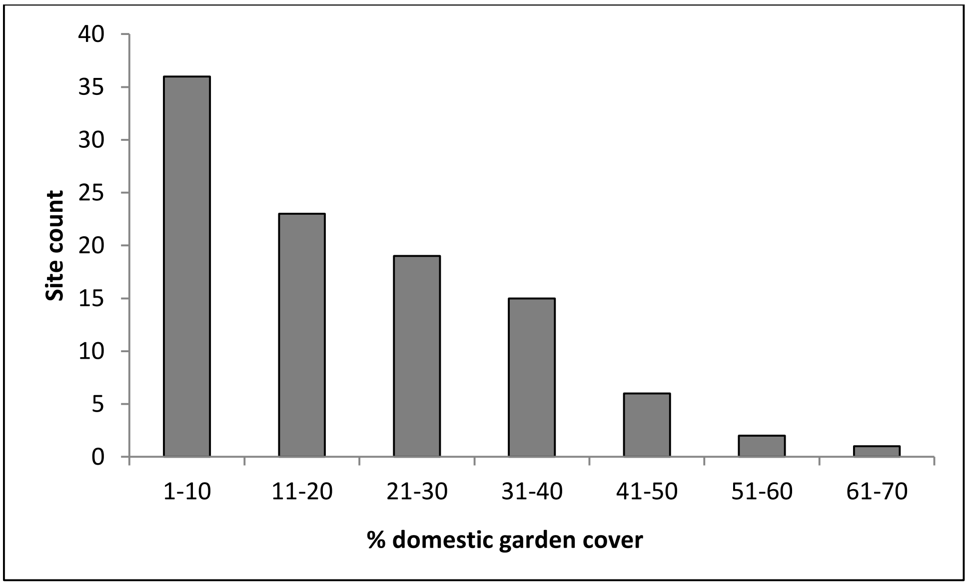

Figure 2: Distribution of OSEIs by domestic garden cover (r^2 linear = 0.95; $p < 0.001$).

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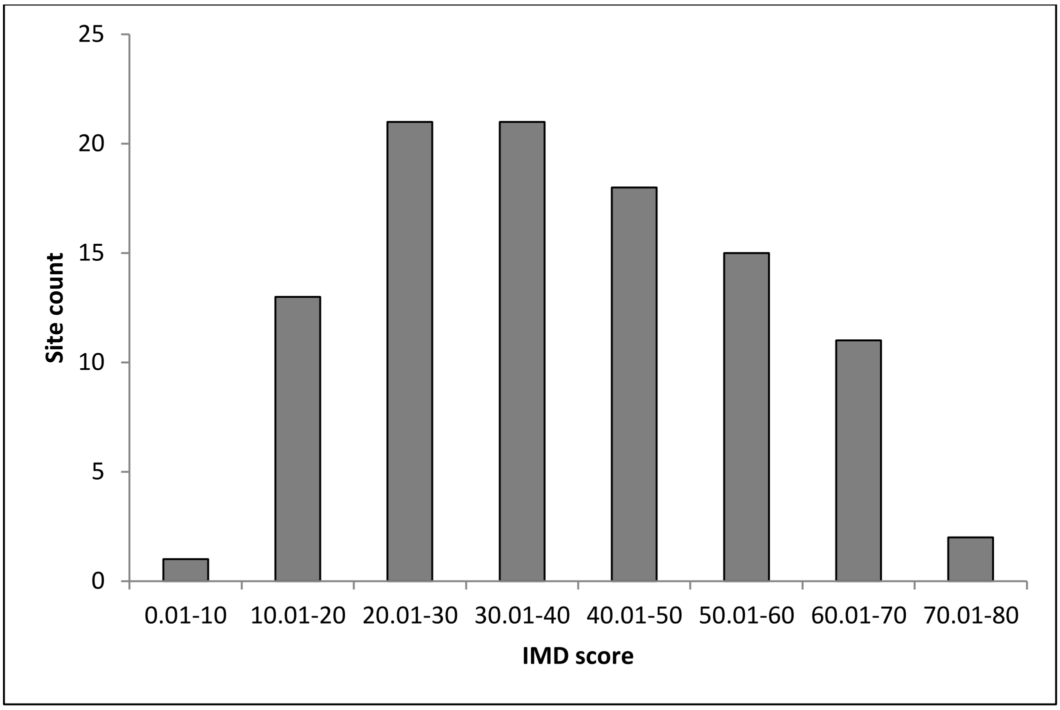

Figure 3: Frequency of OSEI occurrence relative to IMD score (r^2 quadratic = 0.94; p = 0.001).

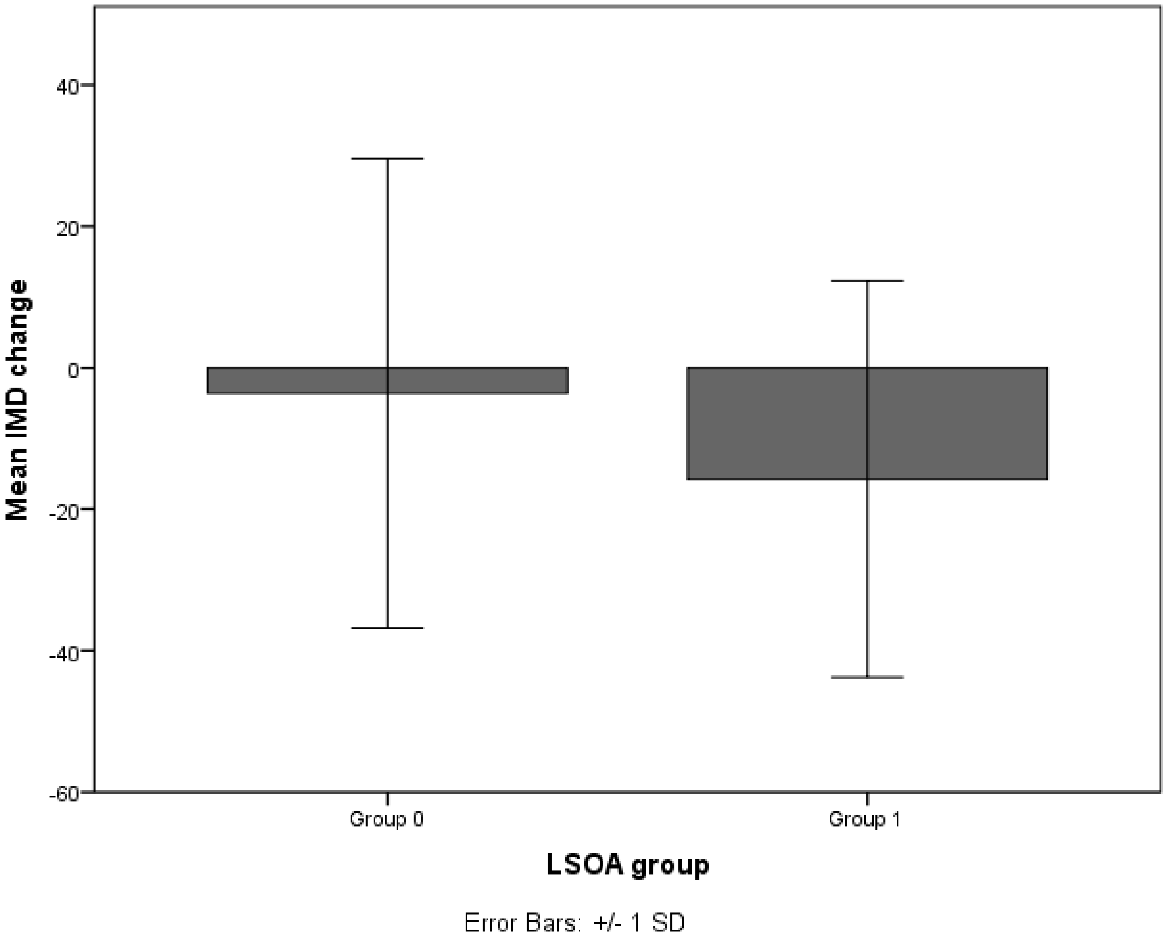

Figure 4: Change in IMD score in LSOA groups 0 and 1.

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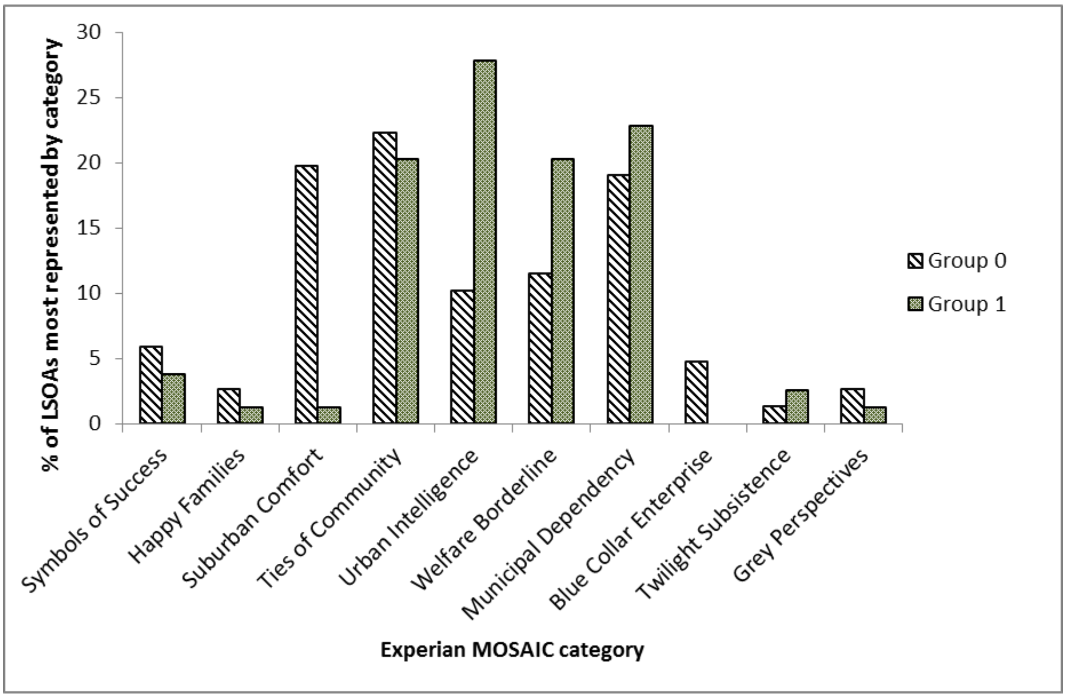

Figure 5: Most representative MOSAIC households in LSOA groups 0 and 1.

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Table 1. MOSAIC UK group descriptions (source: Experian Limited, 2006)

Group	Description
Symbols of Success	Wealthiest 10% of people in the UK. Established in their careers and with substantial equity and net worth.
Happy Families	Families focussed on children, home and career. Tends to be in new suburbs in more prosperous areas of the UK, Mostly white with few minorities
Suburban Comfort	People in comfortable homes in mature suburbs built between 1918 & 1970. Moderate incomes.
Ties of the Community	People whose lives are focussed on local communities. Families concentrated near industrial areas.
Urban Intelligence	Young educated people in inner-city areas. Includes significant minority presence and students. Mix of social classes.
Welfare Borderline	Poorest people in the UK. Urban with significant ethnic minority population.
Municipal Dependency	Poor people in council owned accommodation, dependent on benefits. Primarily white British.
Blue Collar Enterprise	Largely enterprising as opposed to well educated. Low numbers of ethnic minorities.
Twilight Subsistence	Poorer pensioners in council houses. Few ethnic minorities.
Grey Perspectives	Pensioners and comfortably retired people.
Rural Isolation	People in rural areas on low income but high equity. Very few ethnic minorities.